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(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
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1. Your reference — 15386 LgCm

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2. Patent application number *(The Patent Office will fill in this part)* — **9904640.1**

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3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

AEA Technology plc
329 Harwell
Didcot, Oxfordshire, OX11 0RA
United Kingdom

Patents ADP number *(if you know it)* — 6969372004

If the applicant is a corporate body, give the country/state of its incorporation — England and Wales

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4. Title of the invention — Plasma-assisted processing of gaseous media

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5. Name of your agent *(if you have one)* — Paul Austin Wood

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

AEA Technology plc
Patents Department, 329 Harwell
Didcot, Oxfordshire, OX11 0RA

Patents ADP number *(if you know it)* — 6969372001

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6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
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Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	8
Claim(s)	2
Abstract	1
Drawing(s)	1

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Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature M.J. Lofting Date 01.03.99

M.J. LOFTING (On behalf of AEA Technology plc by virtue of a Power of Attorney dated 26th March 1996)

12. Name and daytime telephone number of person to contact in the United Kingdom 01235 432037 Mrs P A Stewart

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Plasma-Assisted Processing of Gaseous Media

The present invention relates to the plasma-assisted processing of gaseous media and in particular to the reduction of the emission of carbonaceous and nitrogenous combustion products from the exhausts of internal combustion engines.

One of the major problems associated with the development and use of internal combustion engines is the noxious exhaust emissions from such engines. Two of the most deleterious materials, particularly in the case of diesel engines, are particulate matter (primarily carbon) and oxides of Nitrogen (NO_x). Increasingly severe emission control regulations are forcing internal combustion engine and vehicle manufacturers to find more efficient ways of removing these materials in particular from internal combustion engine exhaust emissions. Unfortunately, in practice, it is found that combustion modification techniques which improve the situation in relation to one of the above components of internal combustion engine exhaust emissions tend to worsen the situation in relation to the other. Even so, a variety of systems for trapping particulate emissions from internal combustion engine exhausts have been investigated, particularly in relation to making such particulate emission traps capable of being regenerated when they have become saturated with particulate material.

Examples of such diesel exhaust particulate filters are to be found in European patent application EP 0 010 384; US patents 4,505,107; 4,485,622; 4,427,418; and 4,276,066; EP 0 244 061; EP 0 112 634 and EP 0 132 166.

In all the above cases, the particulate matter is removed from diesel exhaust gases by a simple physical trapping of particulate matter in the interstices of a porous, usually ceramic, filter body, which is then regenerated by heating the filter body to a temperature at which the trapped diesel exhaust particulates are burnt off. In most cases the filter body is monolithic, although EP 0 010 384 does mention the use of ceramic beads, wire meshes or metal screens as well. US patent 4,427,418 discloses the use of ceramic coated wire or ceramic fibres.

GB patent 2,274,412 discloses a method and apparatus for removing particulate and other pollutants from internal combustion engine exhaust gases, in which the exhaust gases are passed through a bed of charged pellets of material, preferably ferroelectric, having high dielectric constant. In addition to removing particulates by oxidation, especially electric discharge assisted oxidation, there is disclosed the reduction of NO_x gases to nitrogen, by the use of pellets adapted to catalyst the NO_x reduction as exemplified by the use of barium titanate as the ferroelectric material for the pellets.

Also, US patents 3 983 021, 5 147 516 and 5 284 556 disclose the catalytic reduction of nitrogen oxides. However, US 3 983 021 is solely concerned with the reduction of NO to N in a silent glow discharge, the temperature of which is kept below a value at which the oxidation of N or NO to higher oxides of nitrogen does not occur. There is no mention of any simultaneous removal of hydrocarbons.

US patent 5 284 556 discloses the removal of hydrocarbons from internal combustion engine exhaust emissions. The process involved is one of dissociation in an electrical discharge of the so-called 'silent' type, that is to say, a discharge which occurs between two electrodes at least one of which is insulated. The device described is an open discharge chamber. Mention is made of the possible deposition of a NO_x-reducing catalyst on one of the electrodes.

In a broader context, the precipitation of charged, particulate matter by electrostatic forces also is known. However, in this case, precipitation normally takes place upon large planar electrodes of metal screens.

A conventional dielectric barrier plasma assisted gas reactor such as that disclosed in specification US 5,284,556, consists of a plasma volume situated between two electrodes at least one of which has a dielectric barrier in the form of a thick layer of an insulating medium on its inner surface.

In order to generate a plasma in such a device, the potential within the space between the electrodes must reach a critical value before the plasma will ignite. The potential which appears across the main plasma volume is dependent upon the ratio of the capacitance of the dielectric layer and that of the plasma volume because these two entities create a capacitive potential divider. The potential across the plasma volume is inversely proportioned to its capacitance, that is to say, the higher the capacitance of the plasma volume, the lower is the potential difference across it. This effect can cause a serious problem if the plasma volume is filled with a gas permeable material which has a high dielectric constant, such as pellets of barium titanate, because the

potential difference across such a reactor bed may never reach the critical value for the plasma to ignite unless the supply voltage is very high, of the order of tens of kilovolts which may exceed the safe working voltage of the dielectric barrier, or other high voltage components of the power supply.

It is an object of the present invention to provide an improved reactor for the plasma-assisted processing of a gaseous medium.

According to the invention in one aspect there is provided a reactor for the plasma assisted processing of a gaseous medium including a pair of laminar parallel electrodes and a body of dielectric medium positioned symmetrically between the electrodes so as to define a plurality of gas passages extending parallel to the electrodes such that a uniform distribution of electric field occurs across the gap between the electrodes.

According to the present invention in a second aspect there is provided a reactor wherein the electrodes are embedded in a body of dielectric material which extends across the gap between the electrodes and includes a plurality of gas passages extending longitudinally of the body of dielectric material to provide a plurality of electrically equivalent plasma volumes extending in series across the gap between the electrodes.

Preferably the matrix of gas passages in the dielectric medium between the electrodes is adapted to provide a potential difference across the space between the electrodes equal to half the supply voltage.

The surfaces of the gas passages can be coated with a material which is catalytically active in relation to the gas processing to be carried out in the reactor, or the gas passages can be filled with a gas permeable form of such a material, the geometry of the gas passages then being adapted to negate the effects of the capacitive effects of the catalytic material. Alternatively, the dielectric material can itself be chosen to be catalytic in relation to the gas processing to be carried out in the reactor.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which

Figure 1 is a perspective view of the operative part of a reactor embodying the invention for the plasma assisted processing of a gaseous medium, and

Figure 2 is a transverse section of a second embodiment of the invention.

Referring to Figure 1 of the drawings, the operative part 1 of a reactor for the plasma assisted processing of a gaseous medium includes two planar electrodes 1 and 2 to one of which is connected a high voltage supply cable 3. The other electrode has a cable 4 connected to it by means of which it can be connected to a suitable grounding point. The electrodes 1 and 2 are surrounded and separated by a body 5 of a temperature resistant dielectric material such as alumina. A number of identical gas passages 6 extend through the body 5 of dielectric material parallel to the electrodes 1 and 2.

The gas passages 6 are separated by regions 7 of dielectric medium which are of equal thickness and

parallel to the electrodes 1 and 2 so as to form a distributed dielectric barrier between the electrodes 1 and 2.

The electrical isolation of the gas passages 6 from one another prevents the plasma from forming a short circuit between the electrodes 1 and 2. Also, it can be shown that the maximum coupling of power into the plasma volume between the electrodes 1 and 2 occurs when the potential drop across the plasma volume is equal to half the supply voltage. This can be achieved by a suitable choice of the number and cross-section of the gas channels 6.

If desired, the gas channels 6 can be filled with a uniform gas permeable body made of an insulating material which is catalytic towards the gas processing reactions to be carried out in the reactor. Alternatively, the surfaces of the gas passages 6 can be coated with such a material, or the entire body of dielectric can be made of such a material.

In practice, of course, the operative part 1 of the reactor is contained in an envelope which includes inlet and outlet stubs by means of which it can be incorporated in pipework through which the gaseous medium to be processed is caused to flow and means for ensuring that all the said gaseous medium passes through the gas passages 6.

Although the invention has been described in terms of a planar geometry, it is equally applicable to a cylindrical geometry, although in this case, the radial thicknesses of the gas passages will have to vary in order that a uniform radial potential drop be achieved, and such an arrangement is shown in Figure 2.

Referring to Figure 2 a cylindrical reactor body 20 consists of two cylindrical electrodes 21 and 22, which are embedded co-axially in a cylindrical body 23 of a temperature resistant dielectric material. Between the electrodes 21 and 22 are a series of concentric gas passages 24 of cylindrical form separated by radial supporting webs 25. The gas passages 24 are so arranged that they are superimposed radially and each group of gas passages 24 corresponds to the series of gas passages 6 of the Figure 1 embodiment of the invention. (Only two rings of gas passages are shown in the drawing).

Unlike the Figure 1 embodiment of the invention, the radial widths of the gas passages 24 are not the same, but are a function of the distance of the centres of the slats 24 from the inner electrode 22. This is because the radial distribution of the electric field between the electrodes 21 and 22 also is a function of the radial distance from the surface of the inner electrode 22. By a suitable choice of radial widths for the gas passages 24, these two effects can be made to cancel out, giving substantially equal radial electric fields in each of the gas passages 24.

In this case, the inner electrode 22 is arranged to be the high voltage electrode.

A particular use for such reactors is the treatment of the exhaust gases from internal combustion engines to remove particulate carbonaceous and nitrogenous oxides therefrom. In this case, suitable dielectric materials for the body 5, are alpha and gamma aluminas, cordierite, mullite, alumino silicate ceramics or mixtures of these and the surfaces of the gas channels 6 can be coated with a material such as a metal-doped zeolite for example Cu-

doped ZSM-5 or H-exchanged zeolites such as H-ZSM-5. Also, suitable supply voltages are pulsed dc voltages which are of the order of tens of kilovolts with repetition frequencies in the range 50 Hz to 20 kHz. Alternatively an alternating supply voltage may be used. The waveform may have almost any shape, e.g. square, rectangular, sinusoidal, triangular, or saw-tooth.

Claims

1. A reactor for the plasma assisted processing of a gaseous medium, including a pair of laminar parallel electrodes and a body of dielectric medium positioned between them so as to define a plurality of gas passages extending parallel to the electrodes such that a uniform distribution of electric field occurs across the gap between the electrodes.

2. A reactor according to claim 1 wherein the electrodes are embedded in a body of dielectric material which extends across the gap between the electrodes and includes a plurality of gas passages extending longitudinally of the body of dielectric material to provide a plurality of electrically equivalent plasma volumes extending in series across the gap between the electrodes.

3. A reactor according to claim 1 or claim 2 wherein the gas passages are adapted to present a catalytically active surface to the gaseous medium passing through them.

4. A reactor according to claim 1 or claim 2 wherein the gas passages contain a gas permeable body of an insulating material having catalytic properties for the reactions to be carried out in the reactor.

5. A reactor according to any preceding claim wherein the electrodes are planar and the gas passages have a generally rectangular cross-section with their major transverse dimensions parallel to those of the electrodes.

6. A reactor according to any of claims 1 to 4 wherein the electrodes are in the form of two concentric cylinders and the gas passages comprise a plurality of regularly spaced slots of cylindrical form.

7. A reactor according to any preceding claim wherein the arrangement of gas passages is such that the potential drop across the region between the electrodes is equal to approximately half the voltage applied to the reactor.

8. A reactor according to any preceding claim wherein the dielectric material is selected from the group consisting of alpha or gamma aluminas, cordierite, mullite, alumino silicate ceramics or mixtures of these.

9. A reactor according to claim 8 wherein the surfaces of the gas channels are coated with a metal doped zeolite or hydrogen exchanged zeolite.

10. A reactor for the plasma assisted processing of a gaseous medium substantially as hereinbefore described and with reference to the accompanying drawings.

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P.A. Wood
Chartered Patent Agent
Agent for the Applicants

Abstract

Plasma-Assisted Processing of Gaseous Media

A reactor for the plasma-assisted processing of a gaseous medium, including a pair of parallel laminar electrodes with a body of dielectric material positioned symmetrically between them.

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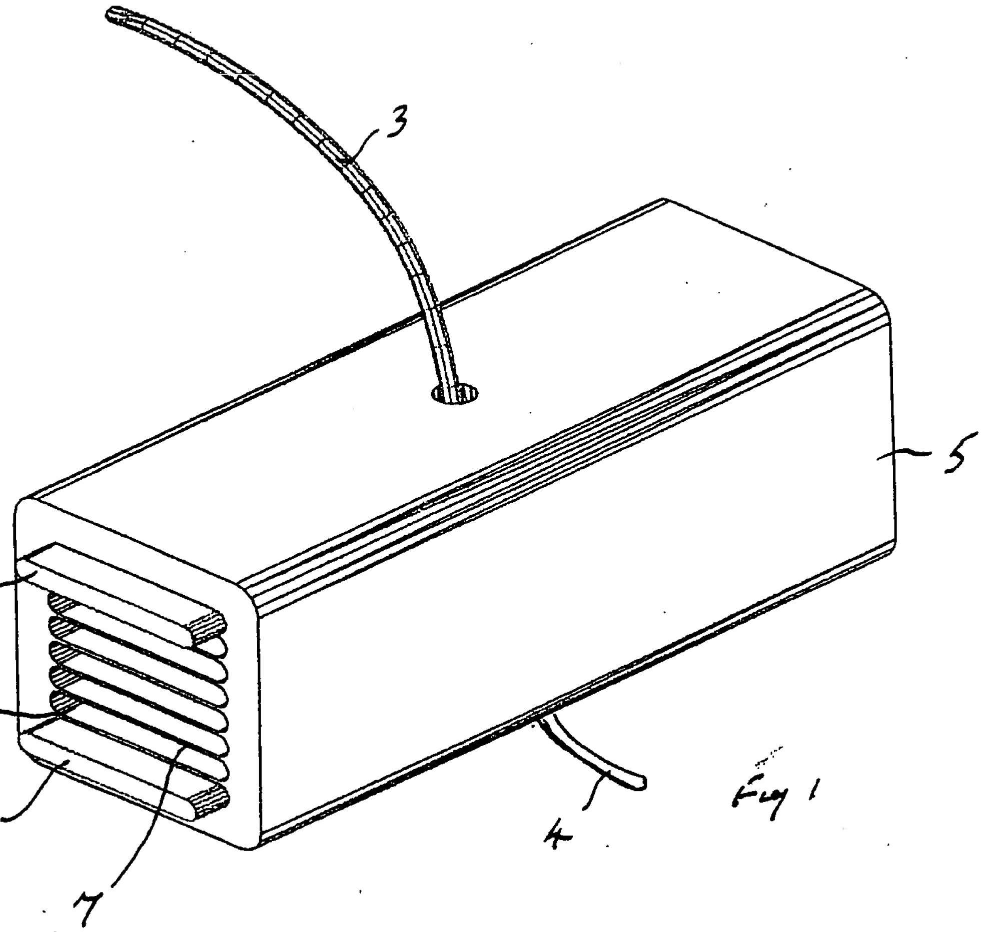

Fig 1

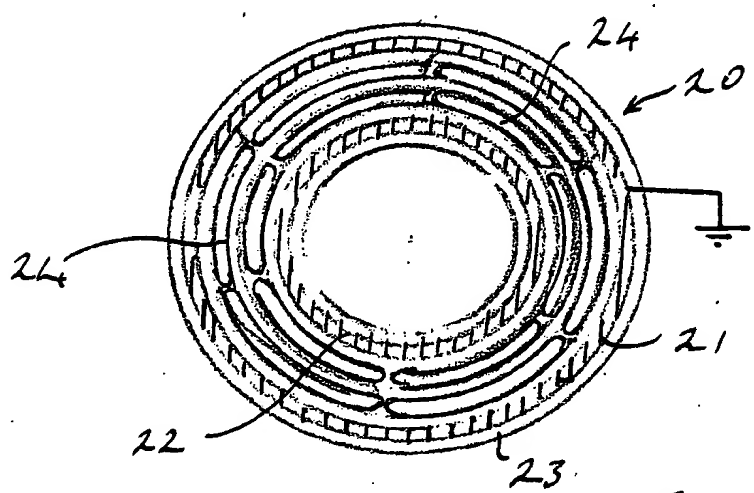

Fig 2.

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